Report No. 3

Third Quarterly Progress Report | Covering the Period 1 January to 31 March 1961

POSITION-LOCATION NETWORK STUDY

Prepared for:

U.S. ARMY SIGNAL RESEARCH AND DEVELOPMENT LABORATORY
FORT MONMOUTH, NEW JERSEY

CONTRACT DA-36-039-SC-84966
DA PROJECT NO. 3E44-02-001-02 (84966)
FILE NO. 40095-PM-60-91-91(1226)

By: J. H. Priedigkeit E. A. Elpel

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

*SRI

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April 1961

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FILE NO. 40095-PM-60-91-91(1226)

By: J. H. Priedigkeit E. A. Elpel

SRI Project No. 3335

Objective: To develop techniques and equipment necessary to demonstrate the automation of a Tactical Direction Finding System composed of AN/TRD-4A HF Direction Finding Sets.

Approved:

C R Alcorn for

E. A. POST, MANAGER RADIO AND WEATHER SCIENCES LABORATORY

fnr D. R. SCHEUCH, DIRECTOR ELECTRONICS AND RADIO SCIENCES DIVISION

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CONTENTS

ILLUSTRATIONS

PURPOSE

The purpose of this contract is to permit the undertaking of a study and development program in accord with Signal Corps Technical Requirements NR. SCL-5775. The results of this program are expected to provide the foundation for the understanding, the techniques, and the equipment to demonstrate the partial automation of a tactical direction-finding system.

To achieve the objectives of this program, an experimental, field-test model of a Radio Direction Finder (RDF) network will be assembled to provide the medium for the investigation of automatic tuning of RDF receivers, and of semi-automatic read-out and transmission of bearing data from remote RDF stations, and for the study of bearing data evaluation and processing techniques.

The over-all program has been divided into three major task areas covering the different phases mentioned, plus a fourth task to provide an integrated over-all study to ensure uniformity in program planning.

ABSTRACT

Four task areas have been established on a program whose objective is to lay a foundation for the development of an automated tactical radio-direction-finding system. These task areas are: (1) investigation of remote tuning of a network of radio receivers by means of a standard 60-word-per-minute teletype circuit, (2) investigation of semi-automatic bearing read-out, evaluation, and transmission, (3) investigation of field-data evaluation and processing techniques, and (4) over-all systems study and planning.

During the third quarter of this project, the major effort ~~has been~~ devoted to the completion and demonstration of the equipments to automatically encode tuning instructions from a master R-390/URR HF radio receiver into teletype signals, and to automatically decode the teletype signals and servo-tune one or more slave R-390/URR HF radio receivers of a direction-finding network.

~~The~~ investigation of semi-automatic bearing read-out, and the preliminary processing of field data ~~have~~ continued. Tentative solutions to these two problems ~~have been~~ formulated, ~~but construction of equipment has not been started.~~

I INTRODUCTION

In the first quarterly progress report, the general problem of using a network of radio-direction-finding stations to determine the location of a particular radio emitter was considered. It was felt that a significant improvement in the operational performance of such a position-location network might be achieved through the use of automatic teletype-tuned radio receivers in the individual direction-finding stations, and through the use of semi-automatic bearing read-out and transmission. It is desirable to use the standard five-unit, 60-word-per-minute teletype circuit for both the transmission of receiver tuning information from the direction-finder-network control station to the geographically remote slave direction-finding stations, and the transmission of bearing information, because the teletype communication circuits are simple and generally available.

The improvement in the operational performance of the position-location network is expected to result (1) from the decrease in set-up time, by minimizing the need for operator-to-operator communications while the receivers of the position-location network are being tuned to the signal frequency, and (2) from the reduction in bearing errors, by the semi-automatic bearing read-out and bearing transmission from the individual direction-finding stations of the position network.

As a result of the efforts on this project during the first and second quarters, it was decided that it would be feasible to add servo-systems to both the MC CHANGE and KC CHANGE shafts of the R-390/URR HF radio receiver so that these functions could be remotely operated by applying appropriate inputs to the servo-systems. Accordingly, master station equipment was designed to encode automatically MC CHANGE and KC CHANGE information into a compatible five-unit teletype format. Slave station equipment was designed to recognize automatically the teletype-encoded tuning instructions, and to generate input signals to the MC CHANGE and KC CHANGE servo-systems. The efforts during the third quarter have been directed toward the construction, testing and demonstration of the master and slave station equipments for the teletype tuning of the R-390/URR HF radio receiver.

There have been no publications prepared or lectures made during this report period. Monthly Performance Summaries 6, 7 and 8, covering the periods 1 January 1961 to 1 April 1961 were submitted to the Contracting Officer and Contract Technical Monitor.

Reproduction of the first quarterly progress report was completed and copies were mailed from SRI on 27 March 1961.

Mr. Harold Jaffe and Mr. Melvin Weiner of USASRDL visited Stanford Research Institute on 28 and 29 March 1961 to see a demonstration of the equipment developed for the remote tuning of R-390/URR radio receivers with information transmitted by standard teletype signals. With the approval of Mr. Harold Jaffe, this equipment was also demonstrated on 21 April 1961 to Mr. Harry Richter and Mr. Marvin Clinch of RADL and to personnel from the AN/GLR-4 program office of the Reconnaissance Systems Laboratory of Sylvania Electric, Mountain View, Calif.

II TASK ONE--REMOTE TUNING OF RECEIVERS

The effort on this task has been directed toward the completion, testing and demonstration of one master and three slave station equipments to demonstrate the remote-tuning of modified R-390/URR HF radio receivers by teletype signals.

Figures 1 and 2 show the equipments comprising the master and slave stations. The master station has provision for automatically encoding, into standard teletype format, tuning instructions pertaining to the MC CHANGE and KC CHANGE adjustments of the master station R-390/URR receiver. This tuning information is automatically transmitted by pressing the MC CHANGE READ and KC CHANGE READ buttons on the master station control panel.

The slave station has provision for automatically recognizing the teletype characters containing MC CHANGE and KC CHANGE tuning instructions, and for generating error signals to actuate the MC CHANGE and KC CHANGE servo-systems attached to the MC CHANGE and KC CHANGE controls of the slave station R-390/URR receiver.

Also shown in Figures 1 and 2 are standard military teletype sets which are used to furnish the teletype line current and which may be used to monitor the tuning instructions generated by the master station equipment. The teletype sets may also be used for routine communications between the master and slave station without the need to disconnect the remote tuning equipments from the teletype loop. However, communications traffic and tuning instructions cannot be transmitted simultaneously over a single teletype circuit.

Operation and demonstration of the equipments shown in Figures 1 and 2 have indicated the following performance characteristics:

(1) Tuning instructions are compatible with standard five-unit teletype signal code and may be transmitted over a standard teletype circuit and monitored with a standard teleprinter.

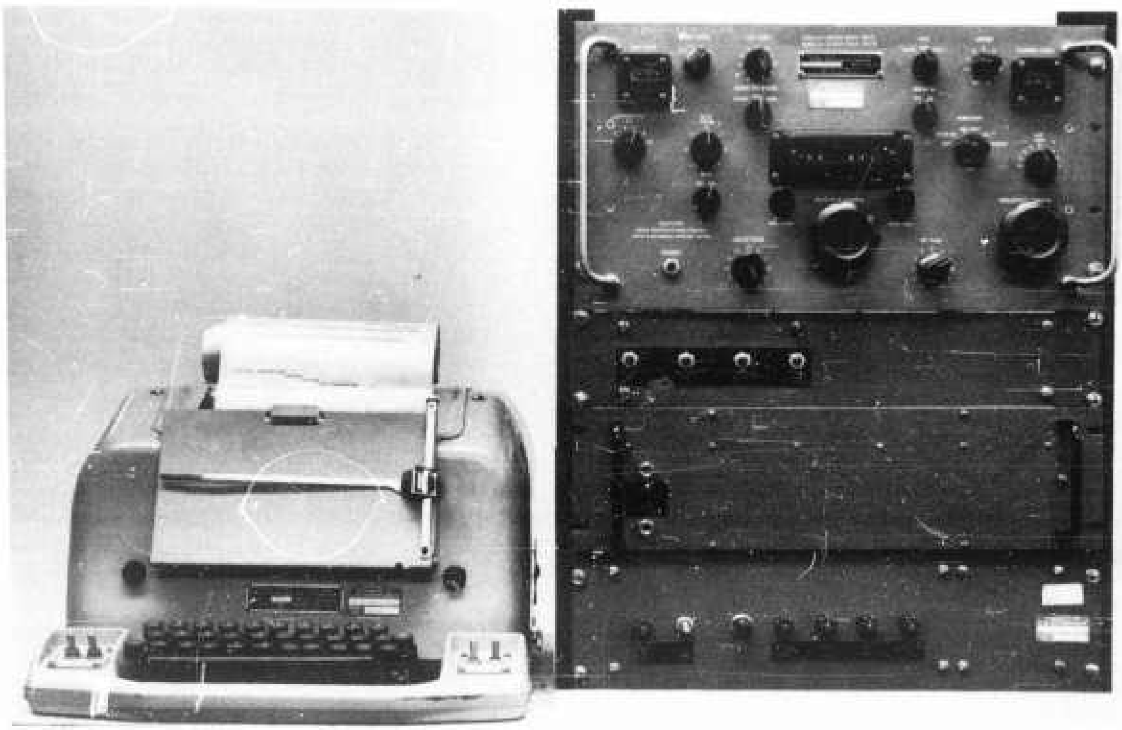


FIG. 1 MASTER STATION EQUIPMENT

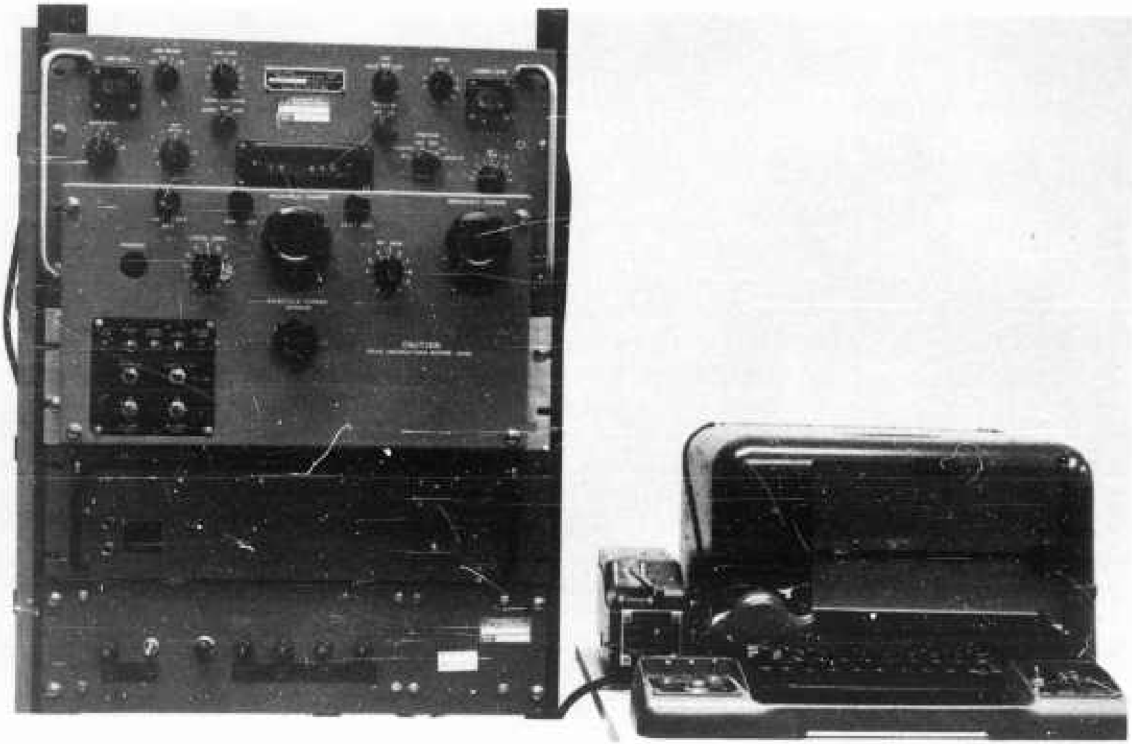


FIG. 2 SLAVE STATION EQUIPMENT

(2) Tuning instructions for the MC CHANGE function of the R-390/URR receiver are automatically encoded and may be transmitted at any time upon command of the master station operator. It requires approximately 0.88 second to transmit the MC CHANGE tuning information.

(3) The MC CHANGE tuning instructions are automatically recognized and converted into an error signal for the MC CHANGE servo of the slave R-390/URR receiver. It requires approximately 15 seconds for the MC CHANGE servo to tune the R-390/URR slave receiver through the entire range of 32 one-megacycle bands.

(4) Tuning instructions for the KC CHANGE function of the R-390/URR receiver are automatically encoded and may be transmitted at any time upon command of the master station operator. It requires approximately 1.41 seconds to transmit the KC CHANGE information.

(5) The KC CHANGE tuning instructions are automatically recognized and converted into an error signal for the KC CHANGE servo of the slave R-390/URR receiver. It requires approximately 15 seconds for the KC CHANGE servo to tune the R-390/URR slave receiver through the entire one-megacycle range of the KC CHANGE dial.

(6) Although it is not possible to send MC and KC tuning instructions simultaneously, it is possible to transmit the KC CHANGE instructions immediately after the transmission of the MC CHANGE instructions. This requires approximately 2.3 seconds. However, because of the memory built into the slave station logic, both the MC and KC servos may operate simultaneously so that the longest possible tuning time becomes approximately 17.3 seconds.

(7) With the use of the R-390/URR frequency calibration techniques, it has been demonstrated that the R-390/URR slave receiver can be remotely servo-tuned to within ±100 cps of the frequency to which the master station R-390/URR receiver is tuned.

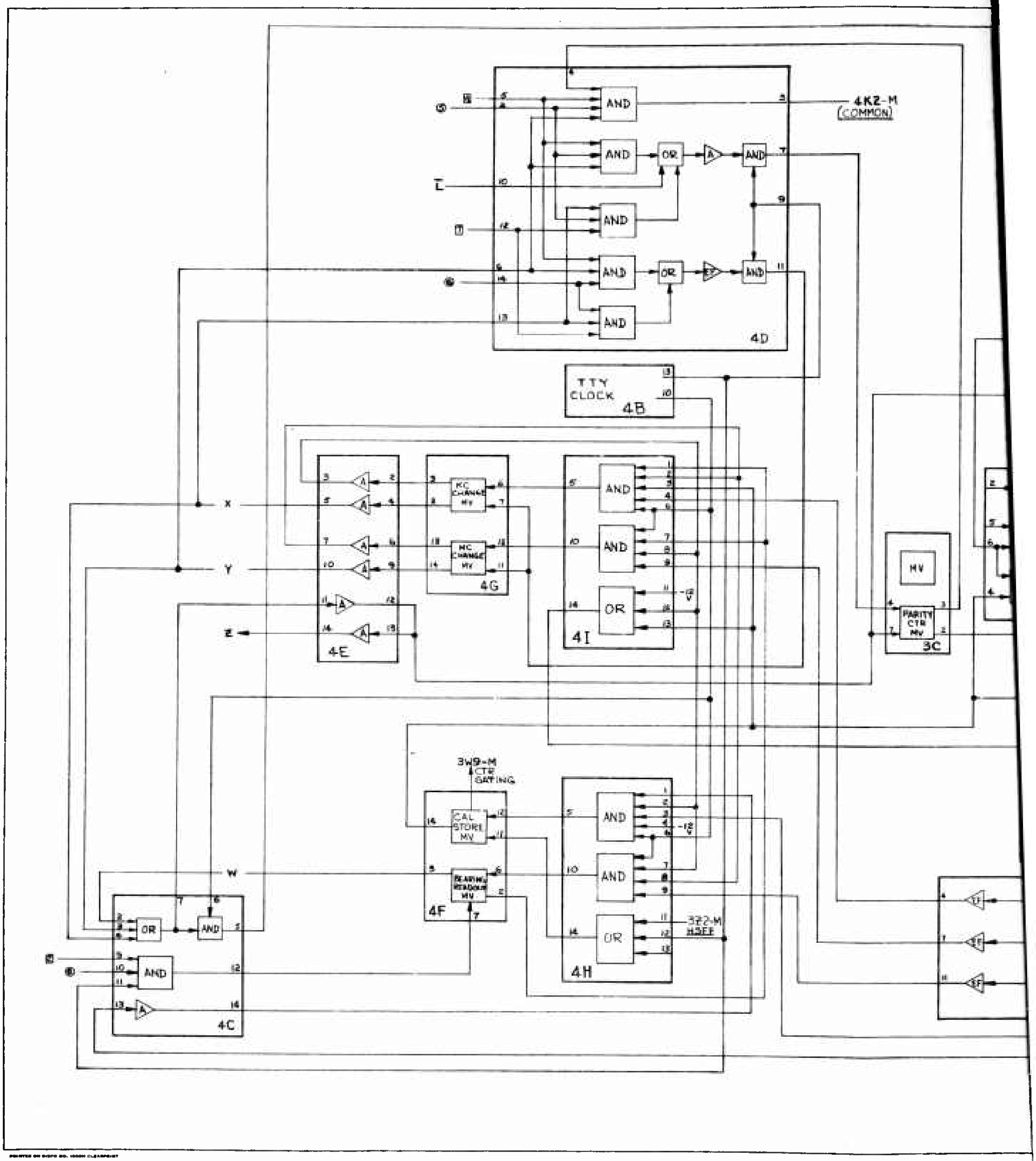
(8) Warm-up time for the master and slave station equipments is essentially zero since these units are completely transistorized.

(9) Gross errors in MC and KC tuning instructions have been minimized by the use of a parity-count technique on both the MC and KC CHANGE messages.

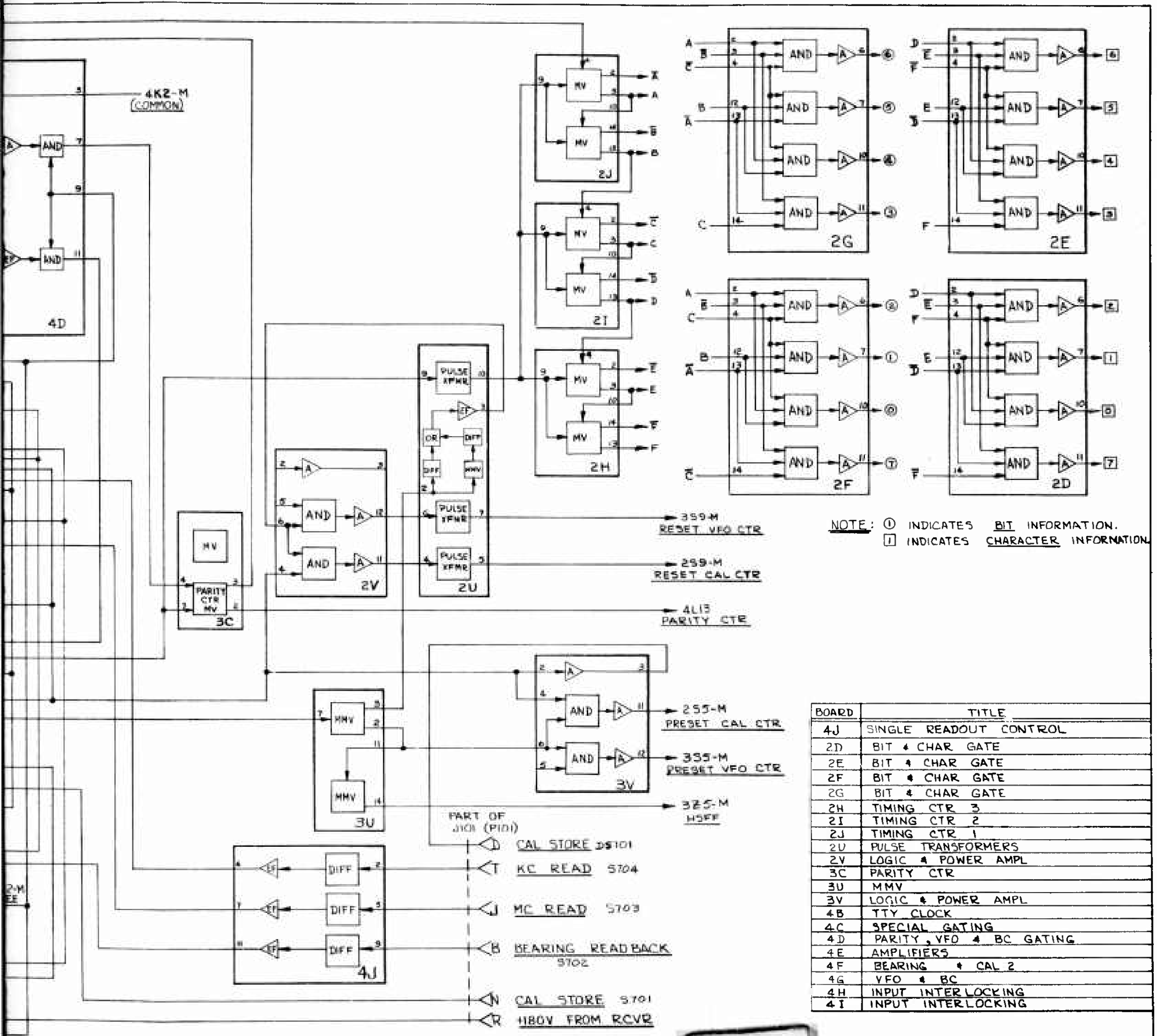
Simplified logic diagrams for the master and slave station are shown in Figures B-1 and B-3 in Appendix B of the First Quarterly Progress Report on this contract.

A detailed logic diagram of the master station is shown in Figs. 3, 4, and 5. A detailed logic diagram of the slave station is shown in Figs. 5, 6, 7, and 8 of this report. It is to be noted that Fig. 5, LOGIC-BINARY VFO COUNTER, is common to both the master and slave stations. The schematic diagrams for most of the plug-in boards referred to on the logic diagrams may be found in Appendix B of the Second Quarterly Progress Report on this contract.

Installation, operation and maintenance instructions, complete with diagrams and theory of operation, are in preparation.

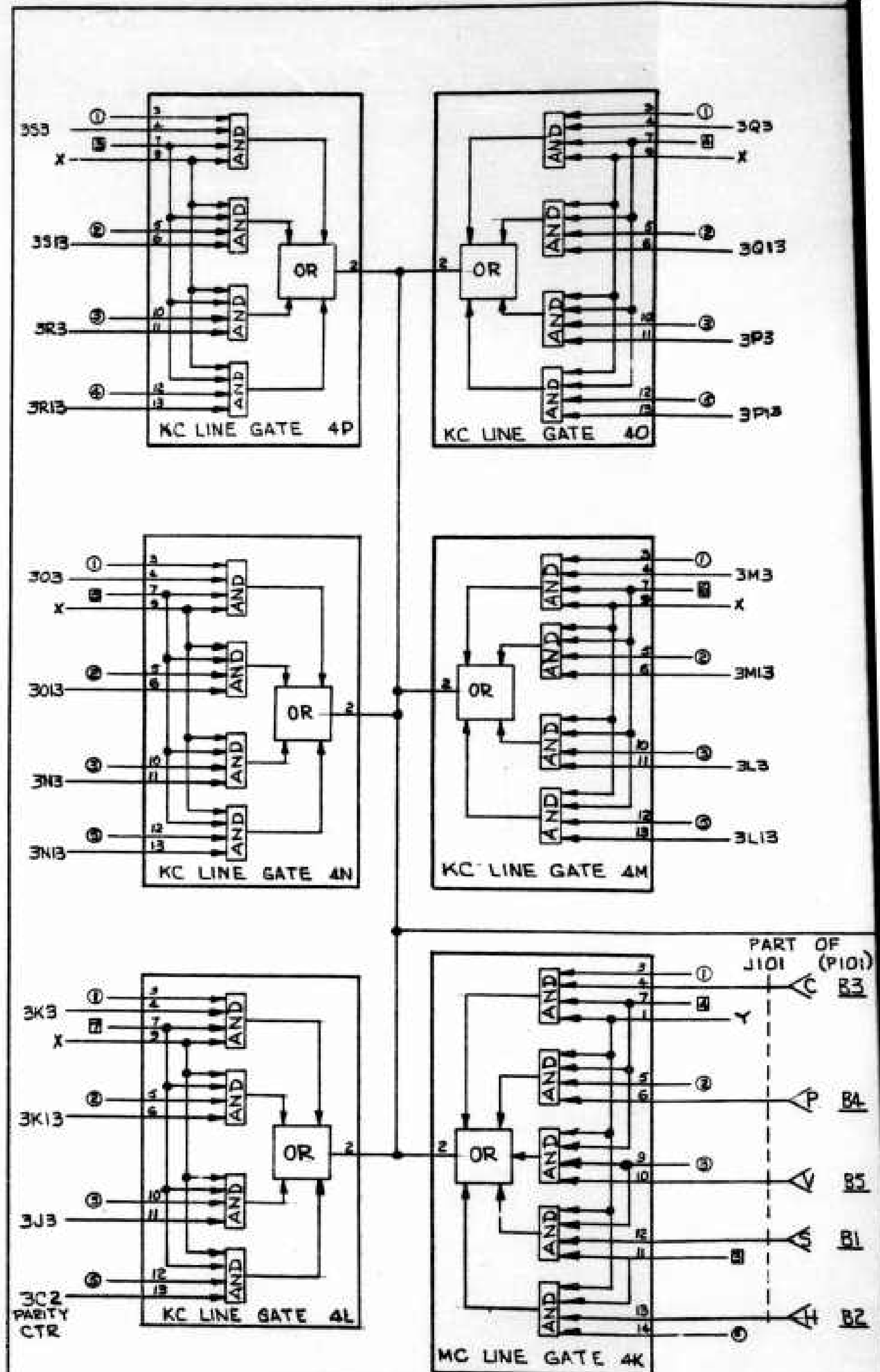


4K2-M
(COMMON)
AND
OR
4D
TTY CLOCK
4B
X
Y
Z
W
4E
KC CHANGE MV
4G
4I
PARITY CTR MV
MV
3C
3W9-M CTR GATING
CAL STORE MV
BEARING READOUT MV
4F
4H
322-M HSFF
4C

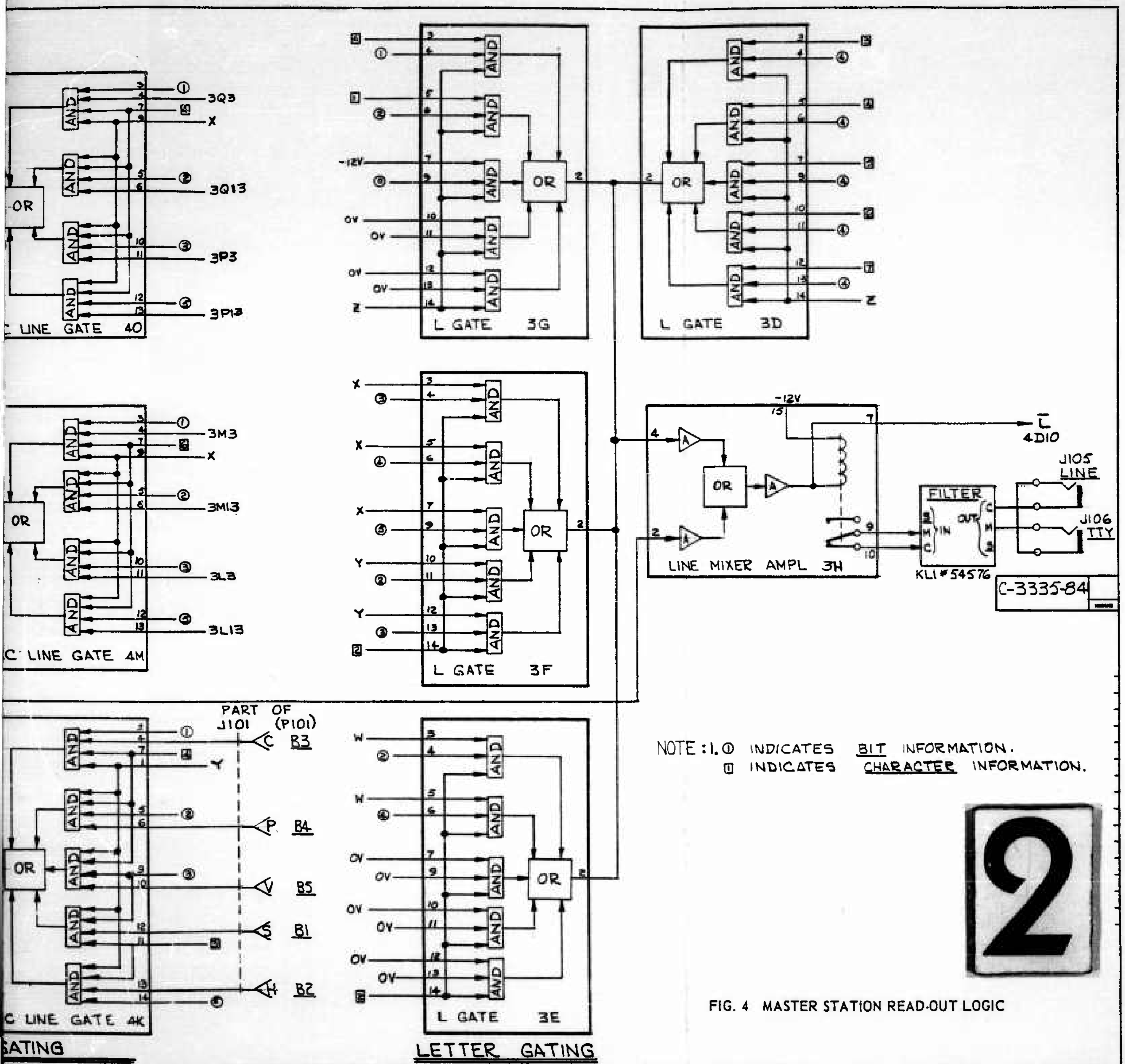


BOARD	TITLE
4J	SINGLE READOUT CONTROL
2D	BIT & CHAR GATE
2E	BIT & CHAR GATE
2F	BIT & CHAR GATE
2G	BIT & CHAR GATE
2H	TIMING CTR 3
2I	TIMING CTR 2
2J	TIMING CTR 1
2U	PULSE TRANSFORMERS
2V	LOGIC & POWER AMPL
3C	PARITY CTR
3U	MMV
3V	LOGIC & POWER AMPL
4B	TTY CLOCK
4C	SPECIAL GATING
4D	PARITY, VFO & BC GATING
4E	AMPLIFIERS
4F	BEARING & CAL 2
4G	VFO & BC
4H	INPUT INTERLOCKING
4I	INPUT INTERLOCKING

FIG. 3 MASTER STATION CONTROL LOGIC



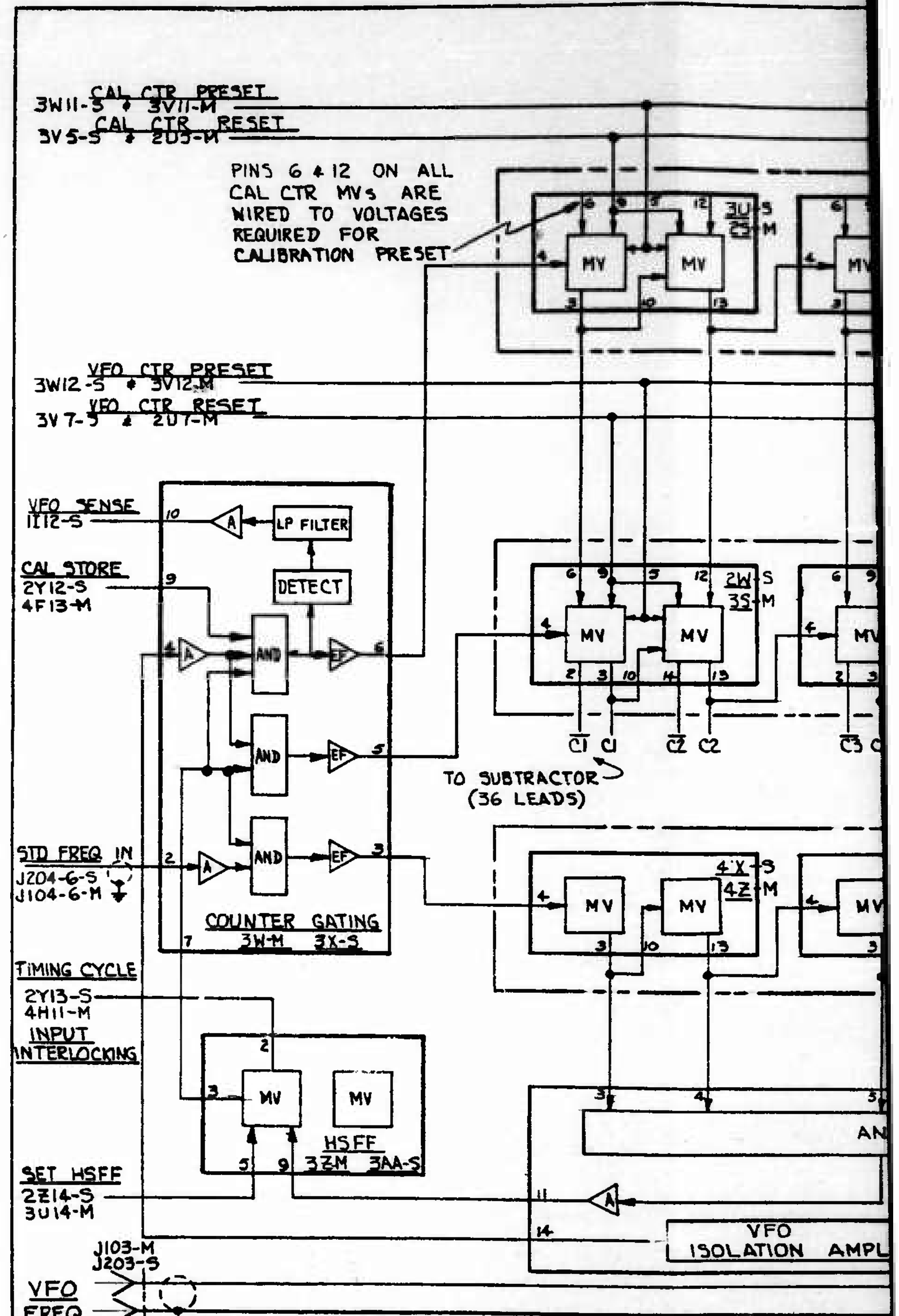
NUMERICAL GATING



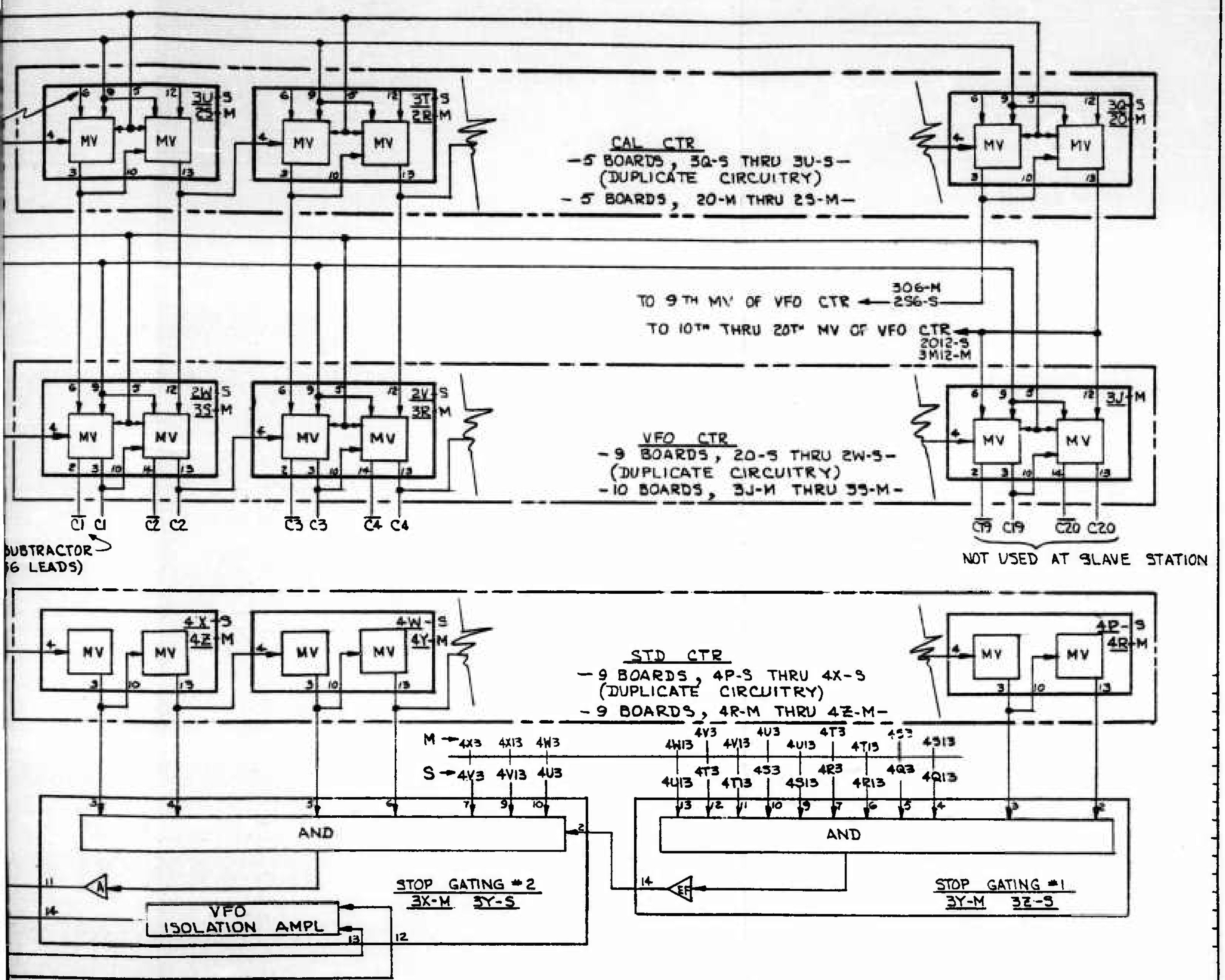
NOTE: 1. ① INDICATES BIT INFORMATION.
◻ INDICATES CHARACTER INFORMATION.

2

FIG. 4 MASTER STATION READ-OUT LOGIC



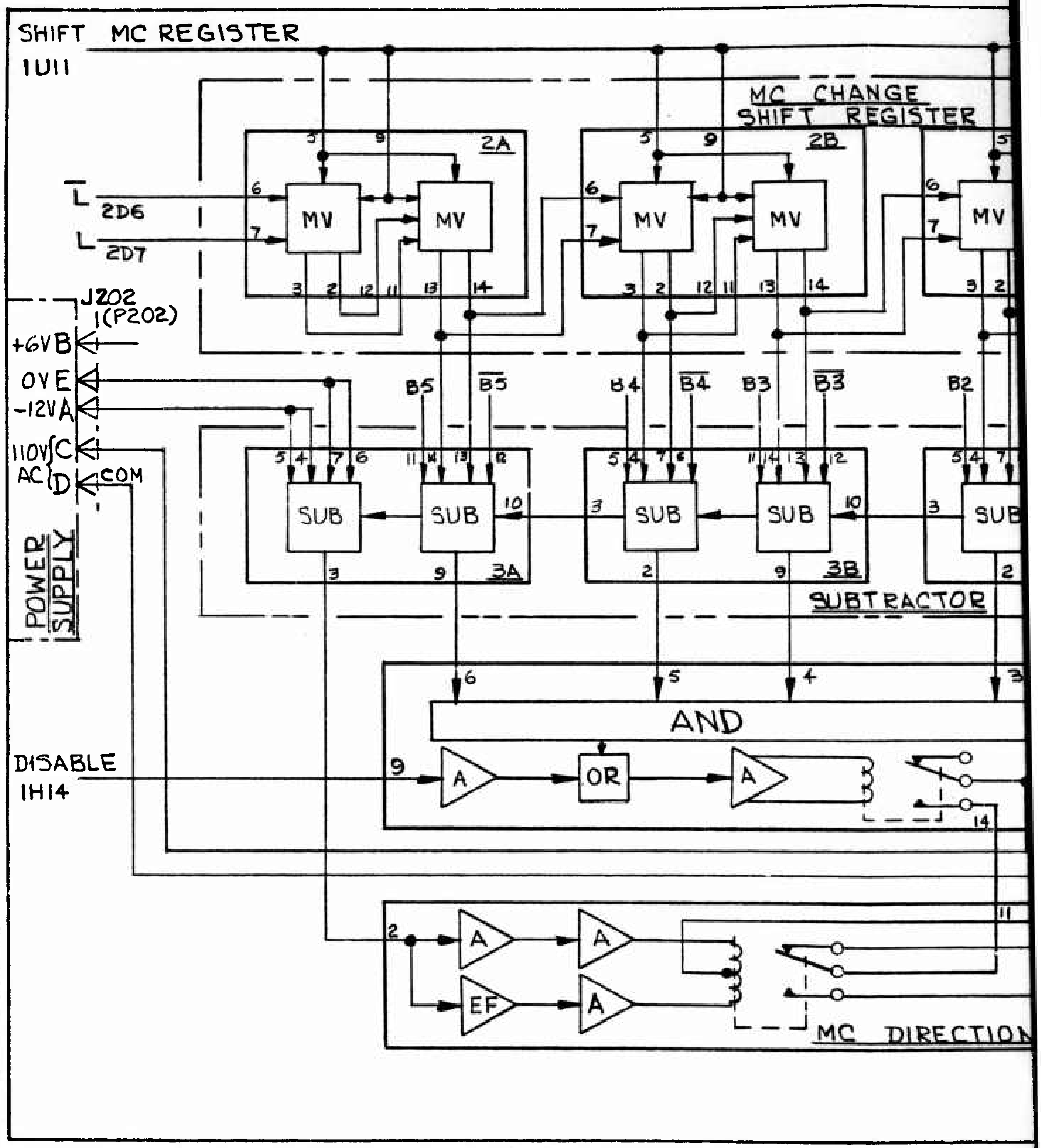
NOTE: 1. MASTER STATION INDICATED BY M FOLLOWING
SLAVE STATION INDICATED BY S FOLLOWING BO



INDICATED BY M FOLLOWING BOARD NO.
NDICATED BY S FOLLOWING BOARD NO.

FIG. 5 BINARY VFO COUNTER LOGIC

2



SHIFT MC REGISTER
1U11
MC CHANGE
SHIFT REGISTER
2A
2B
MV
2D6
2D7
J202
1(P202)
+6V B
0V E
-12V A
110V AC C
D COM
POWER SUPPLY
B5
B4
B3
B2
SUB
3A
3B
SUBTRACTOR
AND
DISABLE
1H14
A
OR
EF
MC DIRECTION

1

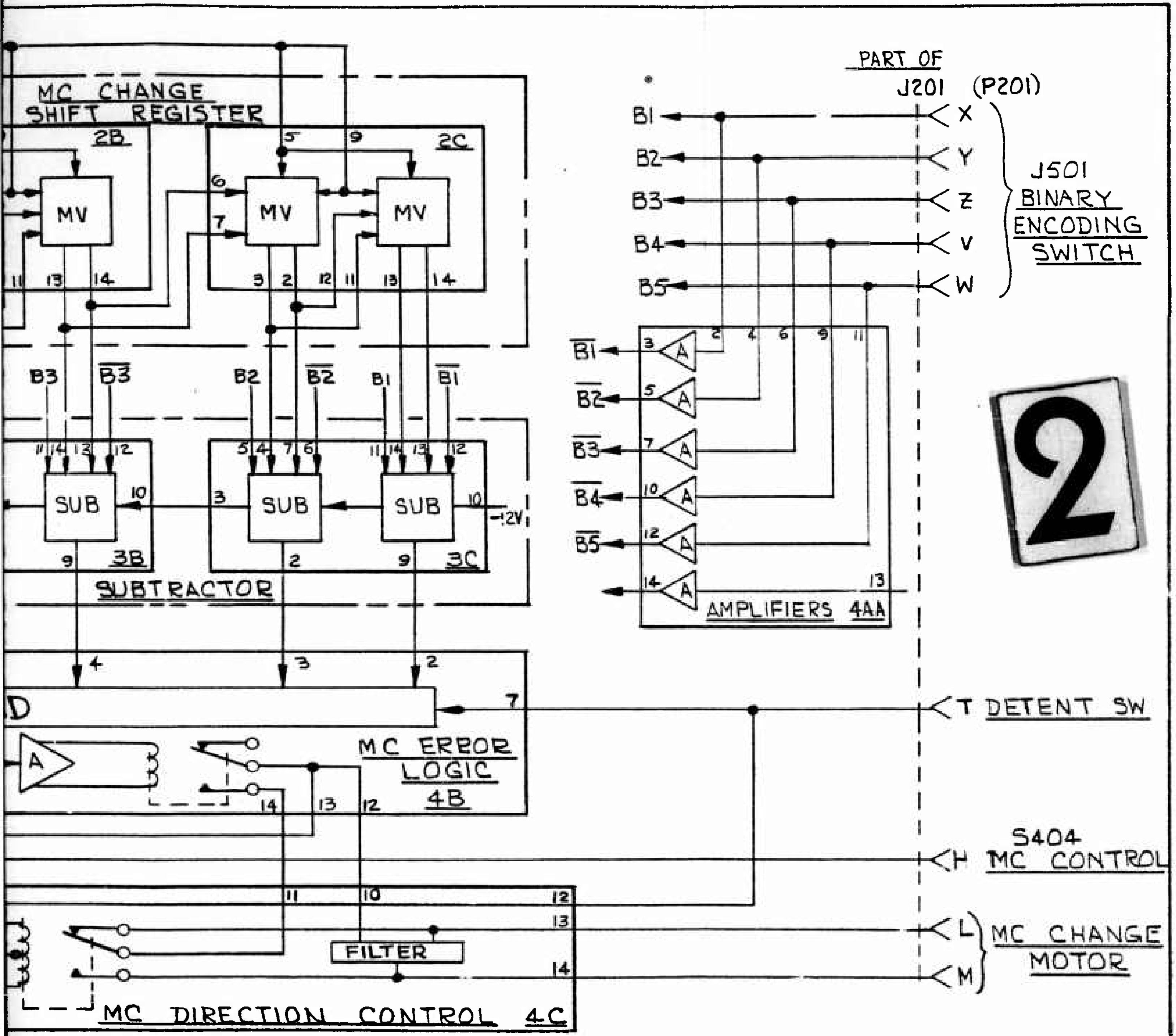
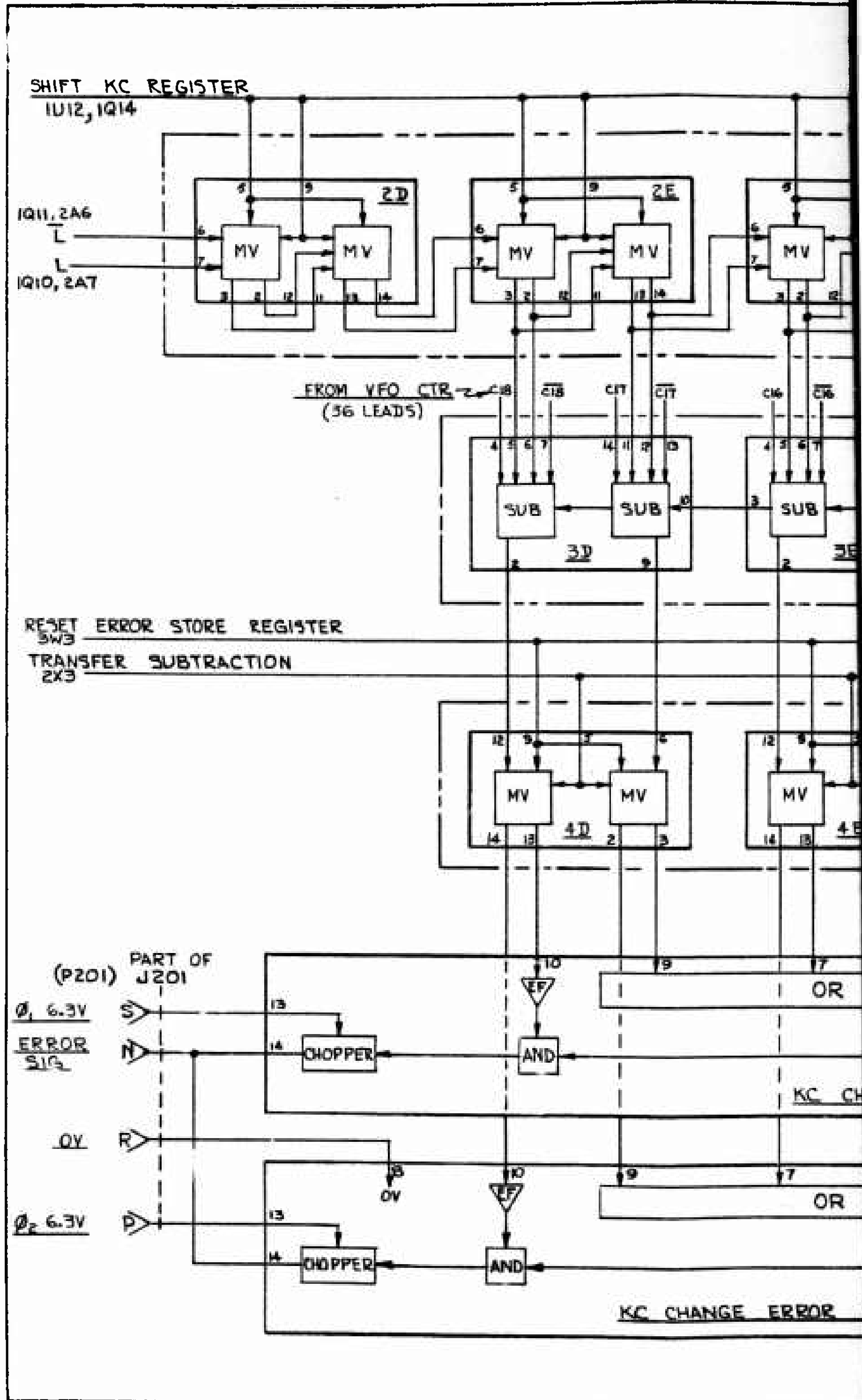


FIG. 6 MC CHANGE SERVO LOGIC


SHIFT KC REGISTER
1U12, 1Q14
1Q11, 2A6
1Q10, 2A7
MV
2D
2E
FROM VFO CTR
(36 LEADS)
C18
C17
C16
SUB
3D
RESET ERROR STORE REGISTER
5W3
TRANSFER SUBTRACTION
2X3
4D
PART OF
J201
(P201)
$\emptyset_1$ 6.3V
ERROR SIG
OV
$\emptyset_2$ 6.3V
CHOPPER
AND
EF
OR
KC CHANGE ERROR

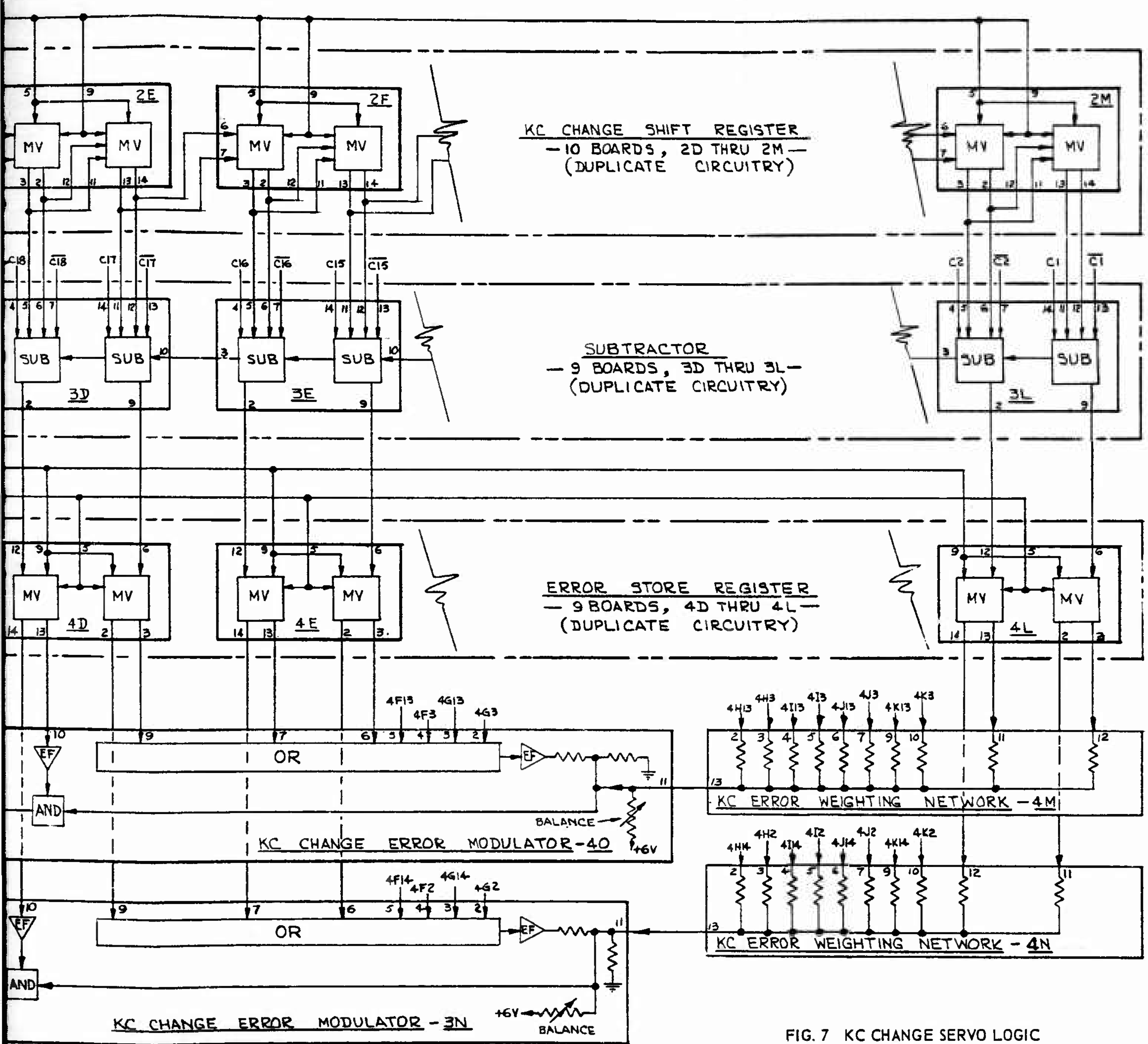
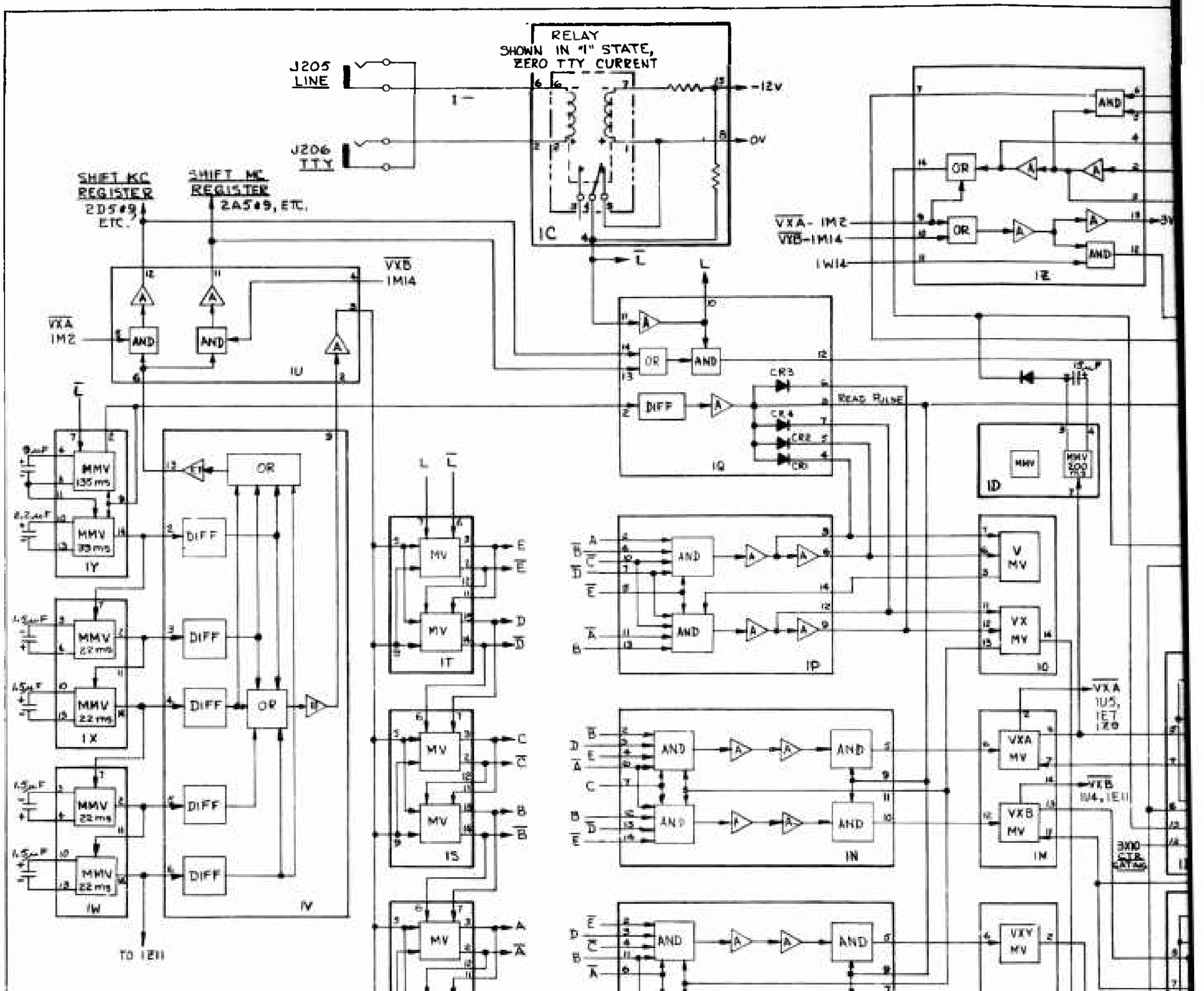


FIG. 7 KC CHANGE SERVO LOGIC

2



BOARD	TITLE
1E	PARITY STORES
1F	CHAR CTR-NBS
1G	CHAR CTR
1H	PARITY & SERVO LOGIC
1I	PARITY & SERVO LOGIC
1J	PARITY CTR-CAL 2
1K	VXY & VXD STORE
1L	VXY & VXD READER
1M	VXA & VXB STORE
1N	VXA & VXB READER
1O	V & VX STORE
1P	V & VX READER
1Q	READ PULSE AMPL
1R	MONITOR REG
1S	MONITOR REG
1T	MONITOR REG
1U	LOGIC & PWR AMPL
1V	DIFFERENTIATOR AMPL
1W	MMV

BOARD	TITLE
1X	MMV
1Y	MMV
1Z	CAL 1 & SPEC GATING
1C	LINE RELAY
2X	LOGIC & PWR AMPL
2Y	TIMING CYCLE LOGIC
2Z	MMV
2AA	MMV
3Y	PULSE XFMRS
3W	LOGIC & PWR AMPL
4Y	LOGIC & PWR AMPL
4Z	LOGIC & PWR AMPL
1D	MMV

1

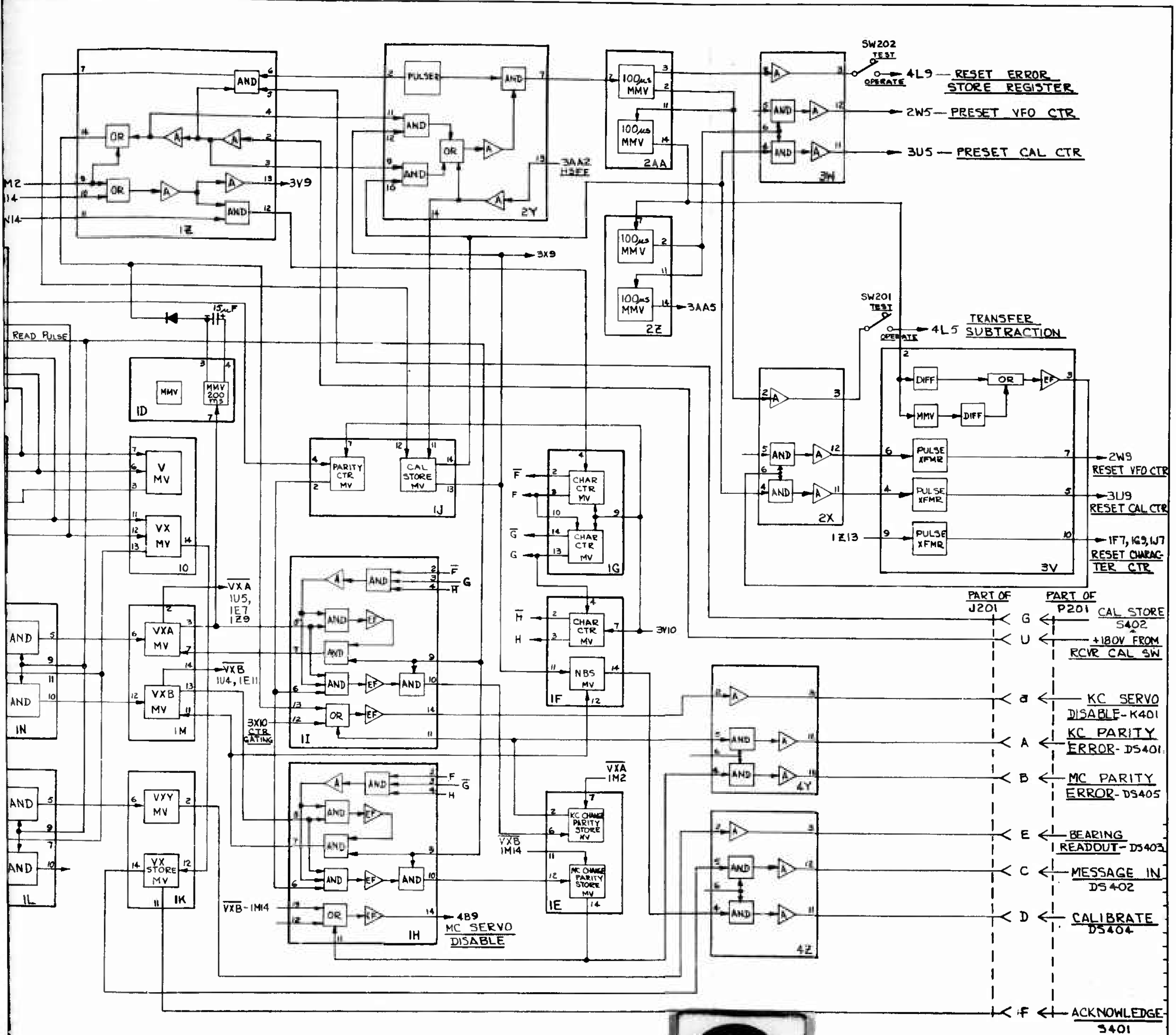


FIG. 8 SLAVE STATION CONTROL LOGIC

2

III TASK TWO--BEARING READ-OUT AND TRANSMISSION

The planning toward the goal of semi-automatic read-out of signal bearings taken with the AN/TRD-4 Direction Finder Set for direct teletype transmission begun last report quarter was continued.

A. System Planning

The system proposed in the Second Quarterly Progress Report on this contract for bearing read-out from each slave station to the master station of a direction-finding network assumed that a half-duplex teletype circuit would be the only means of communication for the network. Thus receiver tuning instructions and the command for bearing read-out are broadcast from the master station and received simultaneously at all slave stations in the direction-finding network. However, because of the assumed use of a single half-duplex teletype loop, the bearing read-out reply from the slave stations must be sequential in time to prevent overlapping transmissions and resulting garbled teletype messages. Since there is an increase in the delay time before the last slave station in the network can reply for every increase in the number of stations in the direction-finding network, it is evident that the bearing read-out is not in real time. For example, in the system discussed in the Second Quarterly Progress Report, there is a delay of 8 seconds between the bearing read-out of the master station and the bearing read-out reply from the third slave station.

One seemingly obvious solution to this problem is to associate a time with each bearing read-out. This, unfortunately, does not solve the problem, since lengthening the reply message to transmit time requires more transmission time and thus further delays the bearing read-out reply from the n^{th} slave station. Also, assuming that the bearing read-out reply messages are identifiable in time, then it becomes necessary to have, at the master station, a means, either human or machine, to sort the reply messages so that bearing read-out messages having the same time identification may be compared. Since both the message transmission and the message sorting require time, the comparison of bearing read-out messages of similar time identifiers must be done after the event. Thus, this system cannot operate in real time. The solution to the problem appears to lie in the direction of reducing the time to transmit bearing read-out information. As the reply time is decreased, the direction-finding network operation will approach real time and, interestingly, the requirement for time identification of messages will diminish since, in the limit, the time of message reception at the master station will be the same as the bearing read-out time at the slave station.

Situations can be envisioned in which it may be desirable to store signal bearing information for some period of time before this information is transmitted to the master station. For example, it may be desirable to average the signal bearings and to transmit only the average of these bearings. Or it may be that the signal is not received at the master station and, at the end of a search period, the master station interrogates the slave stations of the direction-finding network for any bearing information that may have been accumulated on the signal.

In the system proposed in the second quarterly progress report, bearing information was to be stored by leaving the direction finder alidade aligned with the indicated direction of arrival of the signal until the automatic transmission of the alidade position was completed. Although this technique of leaving the alidade in position provides a simple storage system for bearing information, this storage system has very little storage capacity. Unless a bearing read-out is completed before the alidade is moved, as in following the replies from the out-stations in a radio transmitter net, there is no way of retrieving this bearing information.

Careful scrutiny of the proposed simple system to demonstrate the feasibility of semi-automatic bearing read-out indicates that the mode of operation for best performance is related to the system configuration. For example, if only a single half-duplex teletype communication circuit were available for intra-station communication, it would seem that the bearing read-out reply message format should be such that a complete network read-out would require a minimum of time. The shorter this time can be made, the less need there is for time identification and the more nearly the system operation approaches real time. On the other hand if the system configuration permits separate half-duplex teletype circuits to transmit bearing read-out information from each slave station to the master station, it would be possible for all the slave stations to reply simultaneously. If a fixed reply message format were used by all slave stations, the bearing read-out information from all slave stations would simultaneously arrive at the master station and would lag real time by a fixed delay time. This time delay would depend on the message transmission time and the particular place in the message format that the bearing read-out information is placed. Since the bearing read-out replies from the slave stations would occur in parallel, rather than in series as is the case for the single teletype loop system, the length of the reply message is of secondary consideration.

The question of operational advantages gained by data storage at the slave stations appears to be best answered by actual field tests.

In order to answer some of the questions generated during this system planning for equipment to demonstrate the concept of semi-automatic bearing read-out, it now appears that this demonstration equipment should be sufficiently flexible to permit some of the operational concepts to be tried. Figure 9 is a block diagram of a somewhat more sophisticated bearing read-out system than was presented in the Second Quarterly Progress Report on this contract. This system has provision for operation with either a single or multiple teletype circuit, for data storage on a paper tape loop at each slave station, for the insertion of time identification, and for the change of message format.

B. Bearing Encoding Format

The current wide use of standard five-unit teletype code for communication within the field army and the desirability that bearing read-out information be readily understandable by a human operator has led to the adoption of a bearing read-out format in which the signal bearing is printed in degrees on a teletypewriter (see Second Quarterly Progress

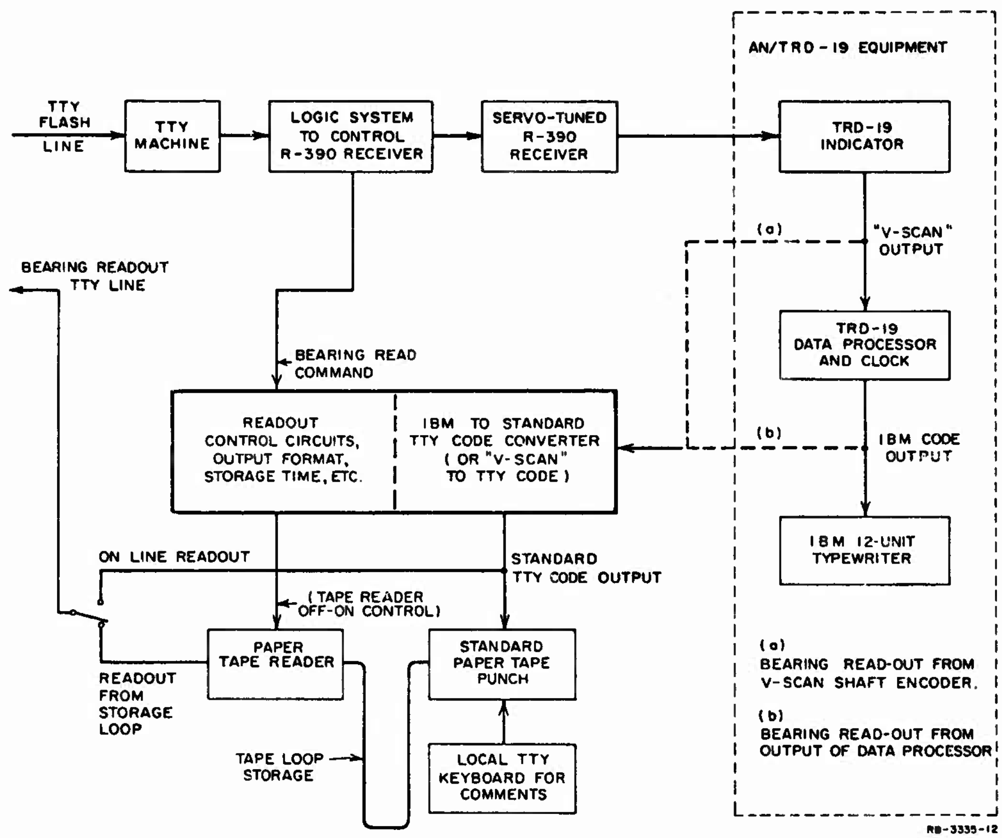


FIG. 9 BEARING READ-OUT SYSTEM

Report). At the time this decision was made, the communication facility for the direction-finding network was envisioned as a single half-duplex teletype loop. Since it now appears that some operational configurations may permit bearing read-out information to be transmitted on individual teletype loops from each slave station to the master station, the choice of bearing format is being reviewed.

It is recognized that with individual communication circuits simultaneous bearing read-out from all slave stations is possible and that to make maximum use of this information it should probably go directly into a computer. Thus the possibility of using FIELDATA code is now being investigated.

C. Bearing Encoder

Since the Digi-Coder* did not appear to be mechanically suitable for use with the AN/TRD-4 direction finder indicator, to convert the alidade position into an electrical signal, the possibility of utilizing the electrical output from the AN/TRD-19 is being considered. The AN/TRD-19 indicator is a modified AN/TRD-4 indicator that has a Librascope, Inc., Model 733 shaft encoder attached to the alidade. The output of this shaft encoder is in binary-coded decimal form with a least significant digit of 0.1 degree.

An inspection of the AN/TRD-19 circuits indicates that it may be possible to connect a diode code-conversion matrix in parallel with the Librascope shaft encoder to obtain a teletype code read-out without disabling the data processing circuitry of the AN/TRD-19 system.

By recognizing the fact that the most significant digit of the 360.0-degree read-out of the shaft encoder is either 0, 1, 2, or 3 and assuming that $\pm 1/4$ degree is acceptable accuracy for a direction-finding system, it becomes possible to simplify the code conversion matrix so that only 88 diodes and 16 transistors are required to convert the binary-coded-decimal bearing information to standard five-unit teletype code. Thus the use of the AN/TRD-19 indicator with a code conversion matrix appears to be a very practical solution to the problem of bearing encoding.

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* A device for the direct conversion of shaft position into standard five-unit teletype code manufactured by Fischer & Porter Co., Warminster, Penn.

IV TASK THREE--DATA EVALUATION AND PROCESSING TECHNIQUES

Because of the effort that has been expended in the construction, testing and demonstration of the equipment for Task I, the time that has been consumed in discussing the effects of field operation on the system planning for Task II, and the delivery date for the work to be accomplished on Task III (31 January 1962), very little effort has been devoted specifically to this Task III. However, the problem of data evaluation and processing has by no means been neglected in making decisions for Tasks I and II. It is anticipated that these decisions will be reviewed, after time permits a more extensive analysis of data evaluation and processing techniques, and after experience has been gained by the field testing of the equipment developed under Tasks I and II.

V TASK FOUR--OVER-ALL SYSTEMS STUDY

Because of the effort placed on the completion of Task I and planning of Task II, comparatively little time was spent on the literature search on direction-finding systems.

VI CONCLUSIONS

The equipment to demonstrate the remote-tuning of the R-390/URR HF radio receiver by means of instructions automatically transmitted over a standard teletype loop has been completed and has operated satisfactorily.

Although the bearing read-out and transmission system described in the second quarterly progress report is adequate to demonstrate the basic fundamentals (i.e., automatic generation and recognition of the bearing read-out command, and automatic bearing read-out in standard teletype code), it is felt that this system lacks the capability of simulating the more sophisticated direction-finding network configurations. A revised system is presented in this report which, it is felt, will be sufficiently flexible to permit the field testing of new concepts of direction-finding network operation.

The modification of the AN/TRD-19 indicator to provide a bearing read-out in teletype code appears to be feasible.

PROGRAM FOR THE NEXT INTERVAL

The master and two slave-station equipments to demonstrate the automatic remote tuning of the R-390/URR HF receiver (Task I) will be completed and shipped to the Contracting Officer. A manual of installation, operating and maintenance instructions, complete with all wiring diagrams and theory of operation, will be prepared for this equipment.

The system planning for the automatic bearing read-out and transmission (Task II) will be completed and implementation of the equipment to demonstrate this system will be begun.

The over-all systems study will be continued to assure the consideration of all facets of the direction-finding problem in this position-location network study.

PERSONNEL

The professional personnel who have made technical contributions to this project during the third report quarter are:

D. F. Babcock	7 percent full time
J. H. Priedigkeit	83 percent full time
E. A. Elpel	80 percent full time
E. E. Spitzer	4 percent full time
J. R. Woodbury	24 percent full time

In addition to the personnel named above, the project has had electronic technician, model shop, report production, and secretarial support.

Biographical information on the above-listed personnel was included in the first and second quarterly progress reports.

AD Accession No.

STANFORD RESEARCH INSTITUTE, Menlo Park, California

POSITION-LOCATION NETWORK STUDY, by J. H. Priedigkeit and E. A. Elpel. Report No. 3, Third Quarterly Progress Report, 1 January to 31 March 1961, 32 pp., 9 Illus.

Contract DA-36-039-SC-84966, DA Project No. 3E44-02-001-02(84966), File No. 40095-PM-60-91-91(1226)

Four task areas have been established: (1) investigation of remote tuning of a network of radio receivers by means of a standard 60-wpm teletype circuit, (2) investigation of semi-automatic bearing read-out, evaluation, and transmission, (3) investigation of field-data evaluation and processing techniques, and (4) over-all systems study.

UNCLASSIFIED

1. Position-Location Network
2. Contract DA 36-039-SC-84966
3. Remote tuning of radio receivers using teletype circuits.
4. Semi-automatic bearing read-out
5. Automated radio-direction-finding system

AD Accession No.

STANFORD RESEARCH INSTITUTE, Menlo Park, California

POSITION-LOCATION NETWORK STUDY, by J. H. Priedigkeit and E. A. Elpel. Report No. 3, Third Quarterly Progress Report, 1 January to 31 March 1961, 32 pp., 9 Illus.

Contract DA-36-039-SC-84966, DA Project No. 3E44-02-001-02(84966), File No. 40095-PM-60-91-91(1226)

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UNCLASSIFIED

1. Position-Location Network
2. Contract DA 36-039-SC-84966
3. Remote tuning of radio receivers using teletype circuits.
4. Semi-automatic bearing read-out
5. Automated radio-direction-finding system

AD Accession No.

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